Installation (Site) Considerations

John Stevens
Sandia National Laboratories
jwsteve@sandia.gov

Basic Considerations

Physical Environment

- Installation location flexible or fixed
  - Some technologies lend themselves to creative siting

Basic Considerations

Physical Environment (cont.)

- Location indoors or outdoors
  - Impact of ambient temperature, elevation on power output
  - Some technologies have a minimum starting temperature
- Natural gas needed? What's the local gas pressure?

FEMP

Capstone MicroTurbine™

CAPSTONE C30 High Pressure Gaseous Fuels

The Product

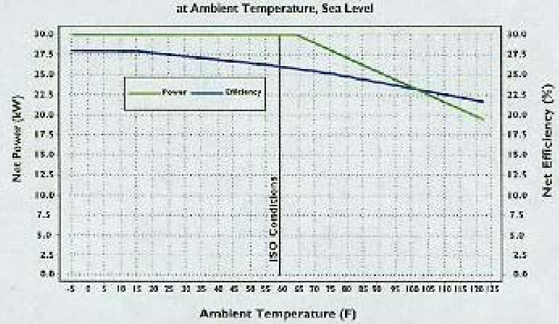
Features

- Load-following 0-30 kW
- 360-528 VAC, 50/60 Hz
  (Stand-alone 360-480 VAC, 10-60 Hz)
  3-phase, 3- or 4-wire wye (4-wire for stand-alone)
  46ARMS/phase max continuous
- Grid-connect and/or stand-alone
- Maintenance-free air bearings
- No liquid lubricants
- No liquid coolants
- Sour gas tolerant (up to 70,000 ppm)
- Digital power controller
- Built-in display and user interface
- Built-in protective relays
- Built-in MultiPacking of 2-20 units (unlimited via grid connect)

Benefits

- Ultra-low emissions
- Minimal maintenance
- Direct2Grid™ interconnection
- No fluid storage, changes, disposal
- Uncontaminated exhaust heat for CHP
- Phase-to-phase balance (0-100%) on stand-alone units
- Small footprint
- Vibration-free, quiet operation
- Easy indoor/outdoor/rooftop siting
- Zero hardware arraying (up to 600 kW)
- Optional remote monitoring

C30 HP Net Power and Efficiency at Ambient Temperature, Sea Level



Compliances
UL 1741
UL 2200
IEEE 519
CEC Rule 21
NYPSC DG
EPA Exempt
CA AQMD Exempt
WY DEQ Exempt
NEMA 3R / IP 14
Others*

UL LISTED

Other packaging options also available.

Full Load Specifications @ ISO Conditions (15°C / 59°F @ sea level)

Performance	Power	Efficiency (LHV)	Heat Rate (LHV)
Natural gas/gaseous propane (52-55 psig)	30 kW net (+0/-1) 38.2 kVA max @ 480 VAC	26% (± 2)	13,800 kJ (13,100 Btu) / kWh

Emissions:

NO_x	<9 ppmV @ 15% O_2 (<0.49 lb/MWh)

Intake/Exhaust

Fuel flow (natural gas/gaseous propane-HHV)	457,000 kJ/hr (433,000 Btu/hr)
Exhaust gas temperature	275°C (530°F)
Mass flow	0.31 kg/s (0.68 lb/s)
Total exhaust energy	327,000 kJ/hr (310,000 Btu/hr)

Dimensions
H: 1900mm (74.8")
W: 714mm (28.1")
D: 1344mm (52.9")

Weight
478 kg (1052 lb)

Sound
65dBA @ 10 m (33 ft)
CE Lwa 98 compliant

* See www.microturbine.com/compliance for detail
Fuel heat content: 27.8 to 93.8 MJ/m³ (760 to 2616 Btu/scf) HHV; natural gas, propane, methane, ethane.
The manufacturer reserves the right to change or modify without notice, the design or equipment specifications without incurring any obligation either with respect to equipment previously sold or in the process of construction. The manufacturer does not warrant the data on this document. Warranted specifications are documented separately.

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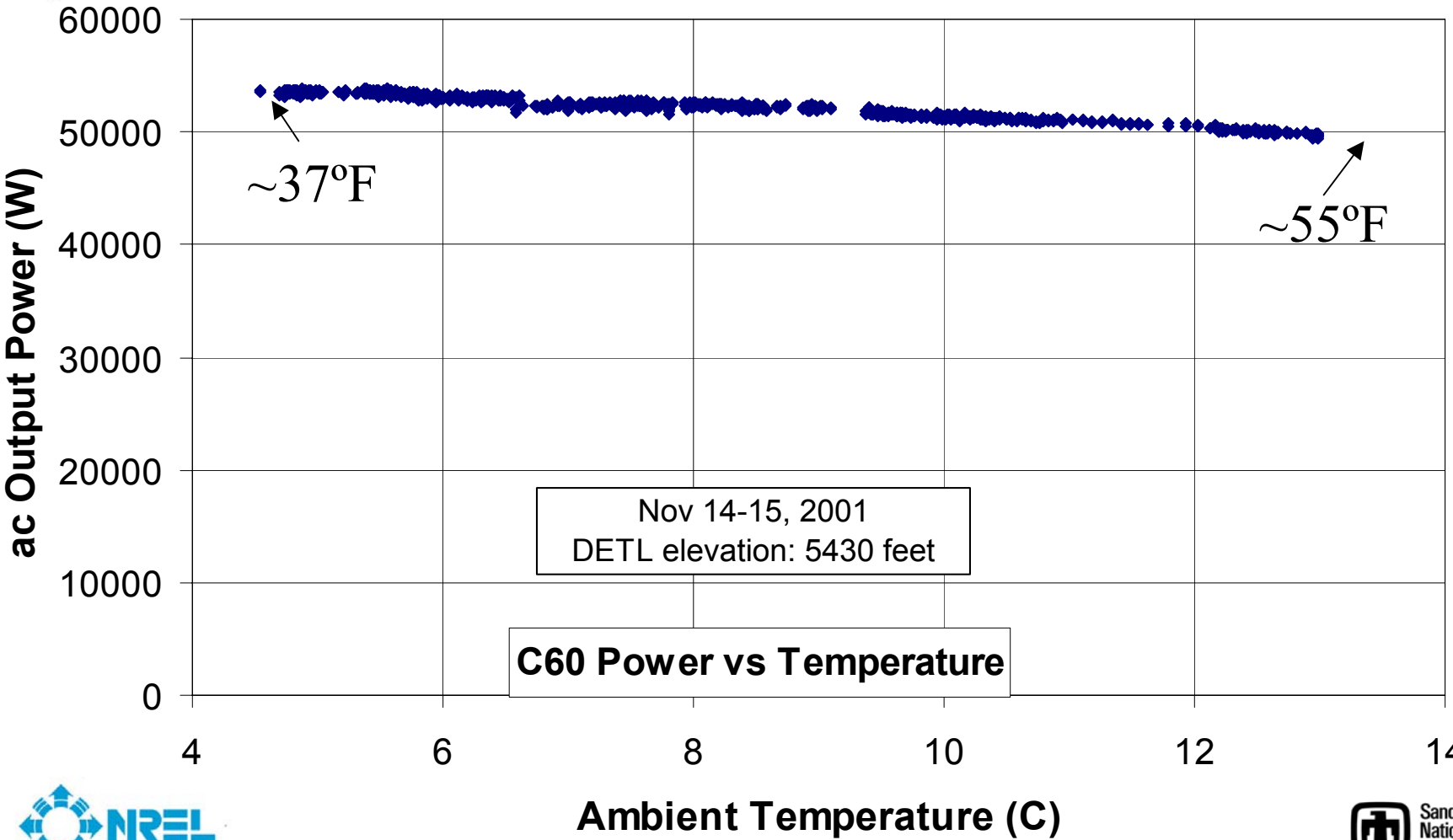
Impact of Elevation on Output



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Basic Considerations

Physical Environment (cont.)

- Location indoors or outdoors
  - Impact of ambient temperature, elevation on power output
  - Some technologies have a minimum starting temperature
- Natural gas needed? What's the local gas pressure?

FEMP

Capstone MicroTurbine™

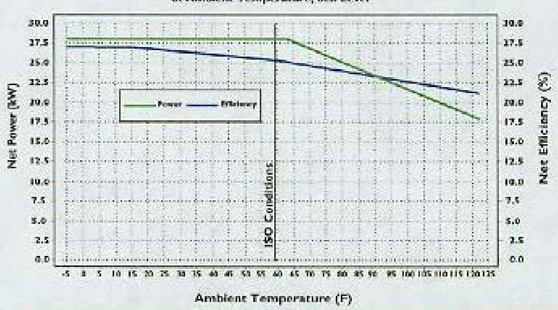
CAPSTONE C30
Low Pressure
Natural Gas

The Product

Features
- Load-following 0-28 kW
- 360-528 VAC, 50/60 Hz
  (Stand-alone 360-480 VAC, 10-60 Hz)
  3-phase, 3- or 4-wire wye (4-wire for stand-alone)
  46ARMS/phase max continuous
- Grid-connect and/or stand-alone
- Maintenance-free air bearings
- No liquid lubricants
- No liquid coolants
- Extended-life RFC w/foil bearings
- Digital power controller
- Built-in display and user interface
- Built-in protective relays
- Built-in MultiPacking of 2-20-units (unlimited via grid connect)

Benefits
- Ultra-low emissions
- Minimal maintenance
- Direct2Grid™ interconnection
- No fluid storage, changes, disposal
- Reduced compressor maintenance
- As low as 0.2 psig inlet pressure
- Uncontaminated exhaust heat for CHP
- Phase-to-phase balance (0-100%) on stand-alone units
- Small footprint
- Vibration-free, quiet operation
- Easy indoor/outdoor/rooftop siting
- Zero hardware arraying (up to 600 kW)
- Optional remote monitoring

C30 LP Net Power and Efficiency at Ambient Temperature, Sea Level



Compliances
UL 1741
UL 2200
IEEE 519
CEC Rule 21
NYPSC DG
EPA Exempt
CA AQMD Exempt
WY DEQ Exempt
NEMA 3R / IP 14
Others*

Other packaging options also available.

Full Load Specifications @ ISO Conditions (15°C / 59°F @ sea level) @ 5 psig

Performance @ 5 psig	**Power**	**Efficiency** (LHV)	**Heat Rate** (LHV)
Natural gas (0.2-15 psig)	28 kW net (+0/-1) 38.7 kVA max @ 480 VAC	25% (± 2)	14,400 kJ (13,700 Btu) / kWh

Emissions:

NO_x	<9 ppmV @ 15% O_2 (<0.49 lb/MWh)

Intake/Exhaust

Fuel flow (natural gas HHV)	440,000 kJ/hr (420,000 Btu/hr)
Exhaust gas temperature	275°C (530°F)
Mass flow	0.31 kg/s (0.68 lb/s)
Total exhaust energy	327,000 kJ/hr (310,000 Btu/hr)

Dimensions
H: 1900mm (74.8")
W: 714mm (28.1")
D: 1344mm (52.9")

Weight
478 kg (1052 lb)

Sound
65dBA @ 10 m (33 ft)
CE Lwa 98 compliant

* See www.microturbine.com/compliance for detail
Fuel heat content: 36.1 to 42.1 MJ/m³ (970 to 1130 Btu/scf) HHV; natural gas, methane. Inlet pressure 0.2-15 psig
The manufacturer reserves the right to change or modify without notice, the design or equipment specifications without incurring any obligation either with respect to equipment previously sold or in the process of construction. The manufacturer does not warranty the data on this document. Warranted specifications are documented separately.

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Basic Considerations

Physical Environment (cont.)

- Physical space must include access for NEC and other maintenance.
- Floor load-bearing capacity
- Impact of vibration

Basic Considerations

Physical Environment (cont.)

- Emissions
  - Exhaust
    - Compliances often shown on data sheets
  - Thermal
    - Adds to building cooling load
  - Acoustic
  - RFI

Capstone MicroTurbine™

CAPSTONE C30 High Pressure Gaseous Fuels

The Product

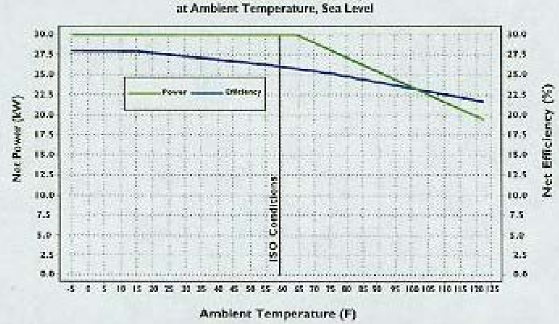
Features

- Load-following 0-30 kW
- 360-528 VAC, 50/60 Hz
  (Stand-alone 360-480 VAC, 10-60 Hz)
  3-phase, 3- or 4-wire wye (4-wire for stand-alone)
  46ARMS/phase max continuous
- Grid-connect and/or stand-alone
- Maintenance-free air bearings
- No liquid lubricants
- No liquid coolants
- Sour gas tolerant (up to 70,000 ppm)
- Digital power controller
- Built-in display and user interface
- Built-in protective relays
- Built-in MultiPacking of 2-20 units (unlimited via grid connect)

Benefits

- Ultra-low emissions
- Minimal maintenance
- Direct2Grid™ interconnection
- No fluid storage, changes, disposal
- Uncontaminated exhaust heat for CHP
- Phase-to-phase balance (0-100%) on stand-alone units
- Small footprint
- Vibration-free, quiet operation
- Easy indoor/outdoor/rooftop siting
- Zero hardware arraying (up to 600 kW)
- Optional remote monitoring

C30 HP Net Power and Efficiency at Ambient Temperature, Sea Level



Compliances
UL 1741
UL 2200
IEEE 519
CEC Rule 21
NYPSC DG
EPA Exempt
CA AQMD Exempt
WY DEQ Exempt
NEMA 3R / IP 14
Others*

UL LISTED

Other packaging options also available.

Full Load Specifications @ ISO Conditions (15°C / 59°F @ sea level)

Performance	Power	Efficiency (LHV)	Heat Rate (LHY)
Natural gas/gaseous propane (52-55 psig)	30 kW net (+0/-1) 38.2 kVA max @ 480 VAC	26% (± 2)	13,800 kJ (13,100 Btu) / kWh

Emissions:

NO_x	<9 ppmV @ 15% O_2 (<0.49 lb/MWh)

Intake/Exhaust

Fuel flow (natural gas/gaseous propane-HHV)	457,000 kJ/hr (433,000 Btu/hr)
Exhaust gas temperature	275°C (530°F)
Mass flow	0.31 kg/s (0.68 lb/s)
Total exhaust energy	327,000 kJ/hr (310,000 Btu/hr)

Dimensions
H: 1900mm (74.8")
W: 714mm (28.1")
D: 1344mm (52.9")

Weight
478 kg (1052 lb)

Sound
65dBA @ 10 m (33 ft)
CE Lwa 98 compliant

* See www.microturbine.com/compliance for detail
Fuel heat content: 27.8 to 93.8 MJ/m³ (760 to 2616 Btu/scf) HHV; natural gas, propane, methane, ethane.
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Basic Considerations

Physical Environment (cont.)

- Tie to existing utilities
  - Electric
  - Gas
  - Hot water
    - May be the most important consideration for CHP installations

A Real-Life Example of Siting Considerations

Installation Details

- Most covered by local building codes
  - Structural, gas and electric hookups, etc.
- Utility interconnection sometimes contentious, confusing
  - Will be site-dependent. Interconnection rules vary by jurisdiction.
  - Check with local utility before proceeding

Varying Interconnection Rules Cause Headaches

- Efforts underway to create national (IEEE) standards that can be adopted by local jurisdiction to provide uniformity
- Goal of these efforts – to remove the current variability in interconnection rules
- Hoped-for end result – all sites will follow the same rules

What Do These Standards Accomplish?

- Example – IEEE 929-2000
  - The standard established PV interconnection criteria
  - This nationally approved document was then adopted by many local jurisdictions as their interconnection standard
  - Requirements in 929 were included as tests in UL 1741
    - leads to products "listed for the application"
    - satisfies local inspectors

Capstone MicroTurbine™

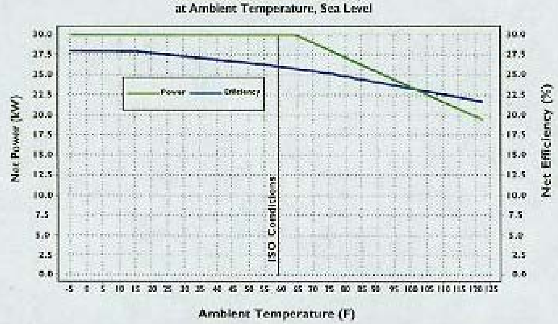
CAPSTONE C30 High Pressure Gaseous Fuels

The Product

Features
- Load-following 0-30 kW
- 360-528 VAC, 50/60 Hz
  (Stand-alone 360-480 VAC, 10-60 Hz)
  3-phase, 3- or 4-wire wye (4-wire for stand-alone)
  46ARMS/phase max continuous
- Grid-connect and/or stand-alone
- Maintenance-free air bearings
- No liquid lubricants
- No liquid coolants
- Sour gas tolerant (up to 70,000 ppm)
- Digital power controller
- Built-in display and user interface
- Built-in protective relays
- Built-in MultiPacking of 2-20 units (unlimited via grid connect)

Benefits
- Ultra-low emissions
- Minimal maintenance
- Direct2Grid™ interconnection
- No fluid storage, changes, disposal
- Uncontaminated exhaust heat for CHP
- Phase-to-phase balance (0-100%) on stand-alone units
- Small footprint
- Vibration-free, quiet operation
- Easy indoor/outdoor/rooftop siting
- Zero hardware arraying (up to 600 kW)
- Optional remote monitoring

C30 HP Net Power and Efficiency at Ambient Temperature, Sea Level



Compliances
UL 1741
UL 2200
IEEE 519
CEC Rule 21
NYPSC DG
EPA Exempt
CA AQMD Exempt
WY DEQ Exempt
NEMA 3R / IP 14
Others*

Other packaging options also available.

Full Load Specifications @ ISO Conditions (15°C / 59°F @ sea level)

Performance	Power	Efficiency (LHV)	Heat Rate (LHV)
Natural gas/gaseous propane (52-55 psig)	30 kW net (+0/-1) 30.2 kVA max @ 480 VAC	26% (± 2)	13,800 kJ (13,100 Btu) / kWh

Emissions:

NO_x	<9 ppmV @ 15% O_2 (<0.49 lb/MWh)

Intake/Exhaust

Fuel flow (natural gas/gaseous propane-HHV)	457,000 kJ/hr (433,000 Btu/hr)
Exhaust gas temperature	275°C (530°F)
Mass flow	0.31 kg/s (0.68 lb/s)
Total exhaust energy	327,000 kJ/hr (310,000 Btu/hr)

Dimensions
H: 1900mm (74.8")
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Weight
478 kg (1052 lb)

Sound
65dBA @ 10 m (33 ft)
CE L_{wa} 98 compliant

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Fuel heat content: 27.8 to 93.8 MJ/m³ (760 to 2616 Btu/scf) HHV; natural gas, propane, methane, ethane.
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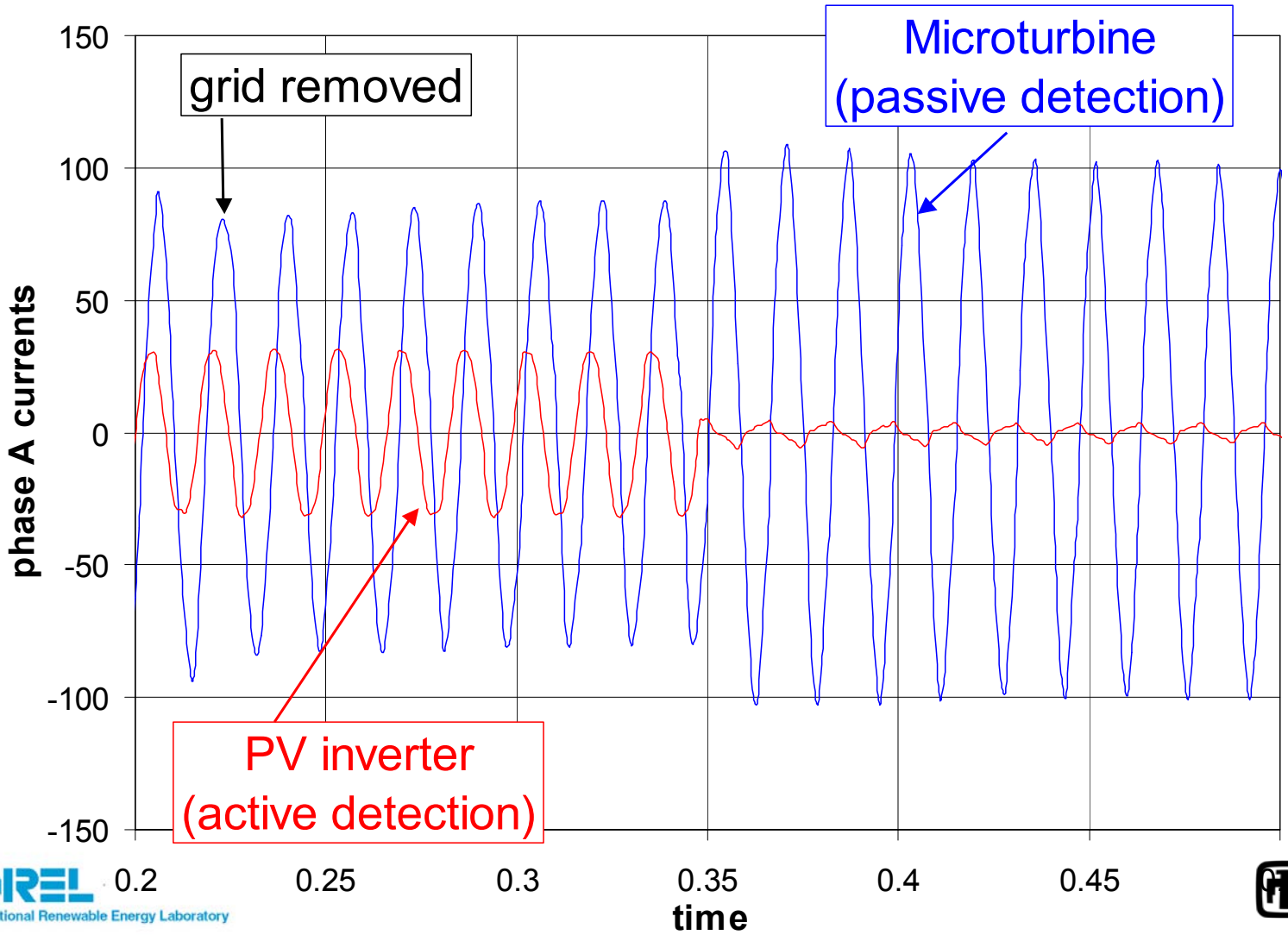
What Else is Covered By these Standards?

- IEEE 929-2000 – Islanding
  - When the utility intends for a line to be de-energized, the DR on that line should not be energizing it
  - Criteria for anti-islanding standardized
  - Standard test procedure established
  - UL 1741 certifies "Non-Islanding Inverters" as result of this process

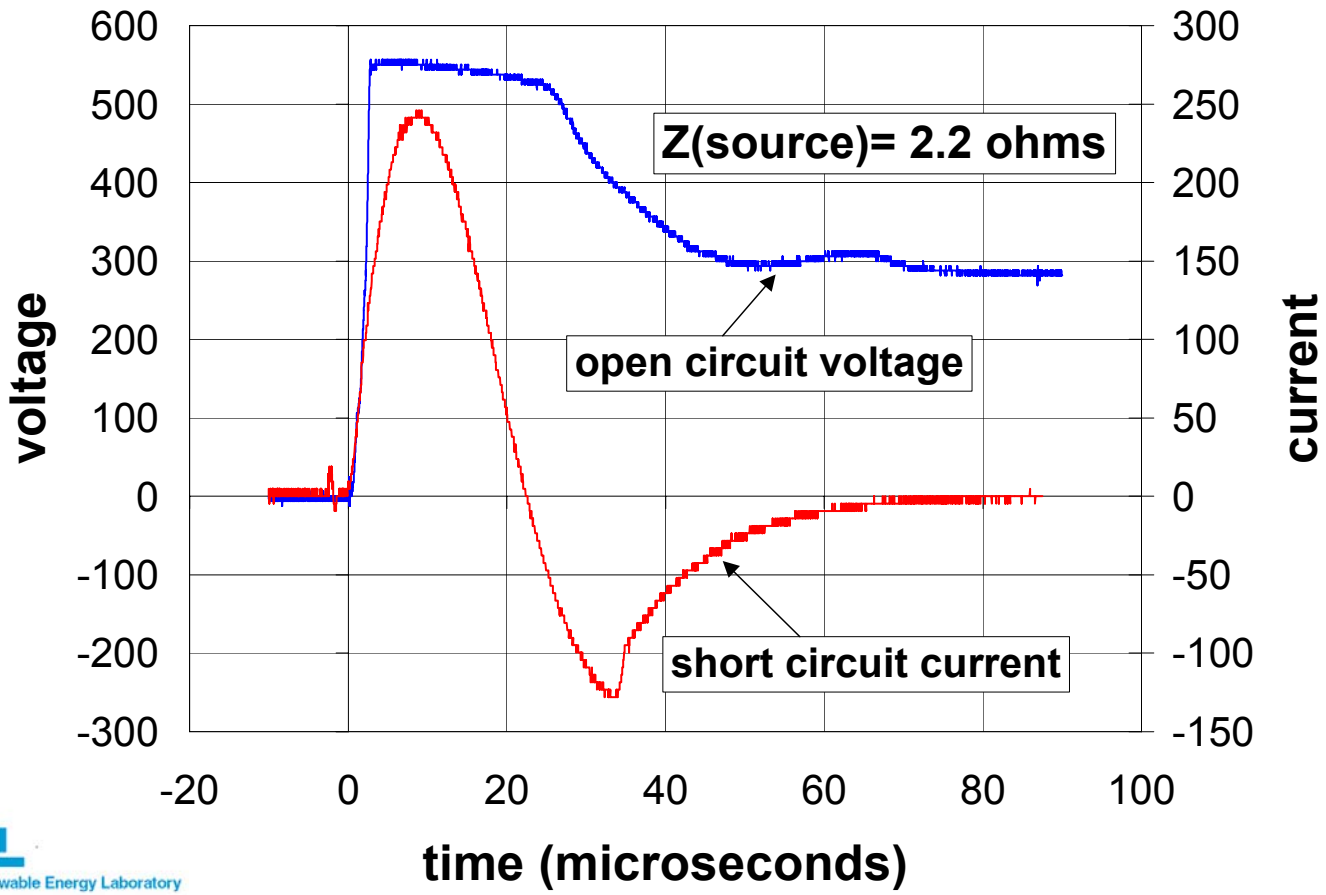
Islanding Test of Two Parallel DG's



Surge Testing to IEEE Standards

Significance Relative to Quantity/Severity of Surges at Site

See BOS Brief #6



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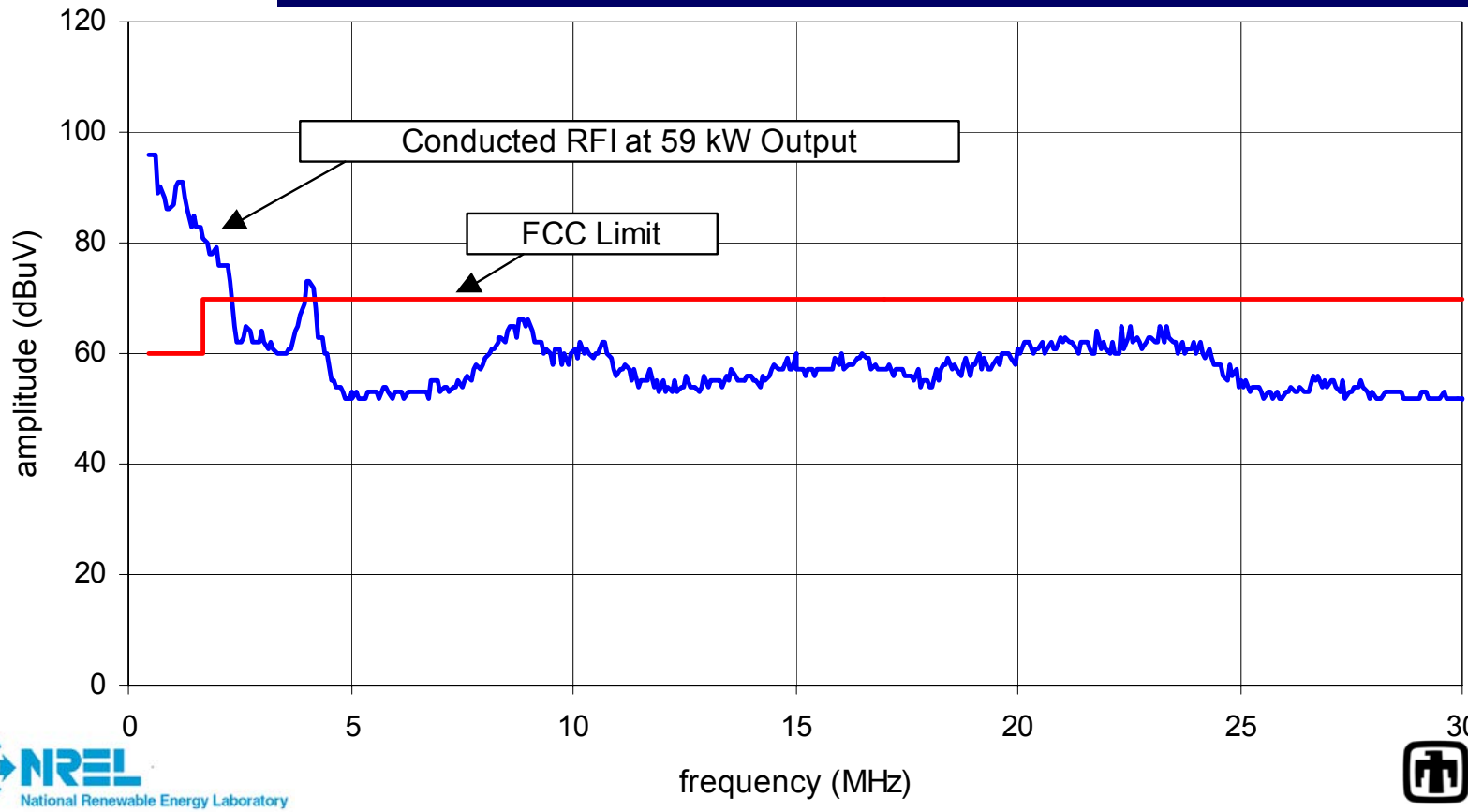
FCC Tests for Radio Frequency Interference

Important to Sites with Susceptibility to RFI

See BOS Brief #4

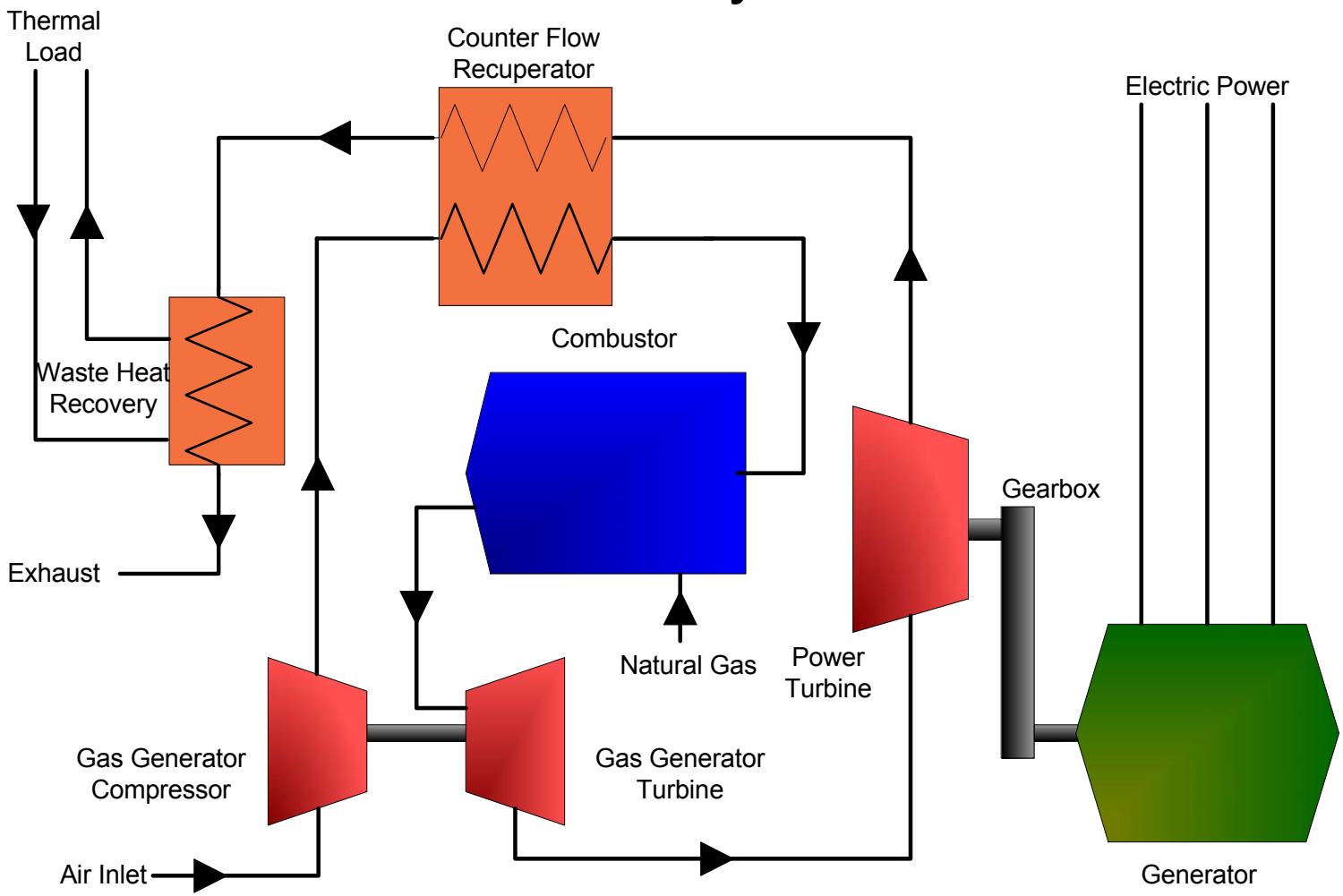


Do You Want Your Microturbine to Recuperate or Not?

Recuperate from what?

The real question is, what do you need more of, electricity or heat?

CHP Microturbine: Cycle Schematic



Capstone MicroTurbine™

"Waste" Gas/Resource Recovery Systems

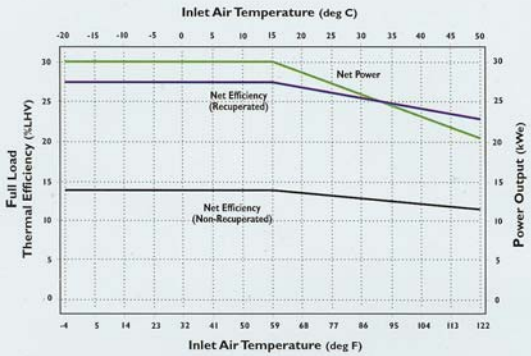
Model 330 MicroTurbine Power Generation Systems

Features

- 30 kW net (ISO conditions)
- 400-480 VAC, 50/60 Hz
  3-phase, 3-wire wye or 4-wire wye, or corner ground delta, 46A/phase max
- ANSI C84.1
- IEEE 519
- 0-7% vol. sour gas capability
- Grid-connect or stand-alone
- Patented air bearings
- Digital power controller
- Air cooled
- Type 3R walk-in enclosures

Benefits

- Burns unprocessed casing gas
- Onsite power from "free" fuel
- Ultra-low emissions
- Ultra-low maintenance
- No liquid lubricants
- No liquid coolants
- Small footprint
- Vibration-free
- Quiet operation
- Multi-unit capable
- Optional remote monitoring



3rd Party Packaging Options

Walk-in, single unit.

Walk-in, dual-unit.

Walk-in, triple-unit.

Other packaging options also available.

Performance Specifications Under ISO Conditions (15°C / 59°F @ sea level)

Performance @ 50 or 60Hz	Full-Load Power	Efficiency (LHV)	Heat Rate (LHV)
Recuperated (52-55 psig)	30 kW net (+/- 1)	27% (+/- 2)	13,300 kJ (12,600 Btu) / kWh
Non-Recuperated (52-55 psig)	30 kW net (+/- 1)	14% (+/- 2)	25,300 kJ (24,000 Btu) / kWh

Emissions:	Recuperated	Non-Recuperated
NO_x	<9 ppmV @ 15% O_2	<35 ppmV @ 15% O_2

Intake/Exhaust:	Recuperated	Non-Recuperated
Fuel flow (Methane-HHV)	440,000 kJ/hr (420,000 Btu/hr)	840,000 kJ/hr (800,000 Btu/hr)
Exhaust gas temperature	261°C / 500°F	518°C / 965°F
Total exhaust energy	305,000 kJ/hr (290,000 Btu/hr)	720,000 kJ/hr (680,000 Btu/hr)

Please call for details on customizable third-party walk-in enclosures pictured above.
All specifications at full-load power. Fuel Heat Content: 26,100 to 93,850 kJ/Nm³ (700 to 2615 Btu/scf) HHV.
Note: The manufacturer reserves the right to change or modify without notice, the design or equipment specifications without incurring any obligation either with respect to equipment previously sold or in the process of construction.

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www.capstoneturbine.com

Bowman POWER The New Wave in Energy

FEMP

TG80 Cogeneration System Performance

Recuperator Status	%	90% Effective Recuperator	No Recuperator
Recuperator In Gas Temp (EGT)	°C	650	NA
Heat Exchanger Inlet Temperature	°C	278	650
Flue Temp	°C	95	95
Air Mass Flow	kg/s	0.81	0.81
Exhaust Mass Flow	kg/s	0.83	0.83
Thermal Output Power *	kW(th)	150	420
Water In Temp	°C	70	70
Water Out Temp	°C	90	90
Water Flow	kg/s	1.8	5.0
Engine Speed	RPM	68000	68000
Electrical Output Power	kW(e)	80	80
Generating Set Efficiency	%	26.0	14.0
Gas Fuel LHV	mJ/m^3	34.88	34.88
Gas Fuel Consumption	m^3/hr	31.8	59.0
System Efficiency (not including GBC)	%	75	87
GBC Power Consumption	kW(e)	3.8	7.1
Net System Electrical Efficiency (Including GBC Loss)	%	24.8	12.8
Net System Power Output (Including GBC Loss)	kW(e)	76.2	72.9
Overall System Efficiency (Including GBC loss)	%	74	86

All values at ISO conditions (sea level and 15°C)
* Includes heat recovered from oil

Output Available: 380-480 V, 3 phase, 50/60 Hz

UK Quality Index

Gross Fuel Calorific Value - UK	mJ/m^3	38.63	38.63
Electrical Efficiency Based on Gross Fuel Consumption	%	23.48	12.64
Thermal Efficiency Based on Gross Fuel Consumption	%	44.09	66.29
Electrical Efficiency QI Index		230	230
Thermal Efficiency QI Index		125	125
QI Index Rating	>105	109	112

Issue A/01

Bowman Power Limited
Ocean Quay, Belvidere Road, Southampton, SO14 5QY England
Telephone +44 (0)23 8023 6700 Fax +44 (0)23 8021 2110
www.bowmanpower.com

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Electrical and Thermal Loads

- Highest electrical output → Recuperate
- Highest thermal output → Don't recuperate
- Highest total energy efficiency → Don't recuperate

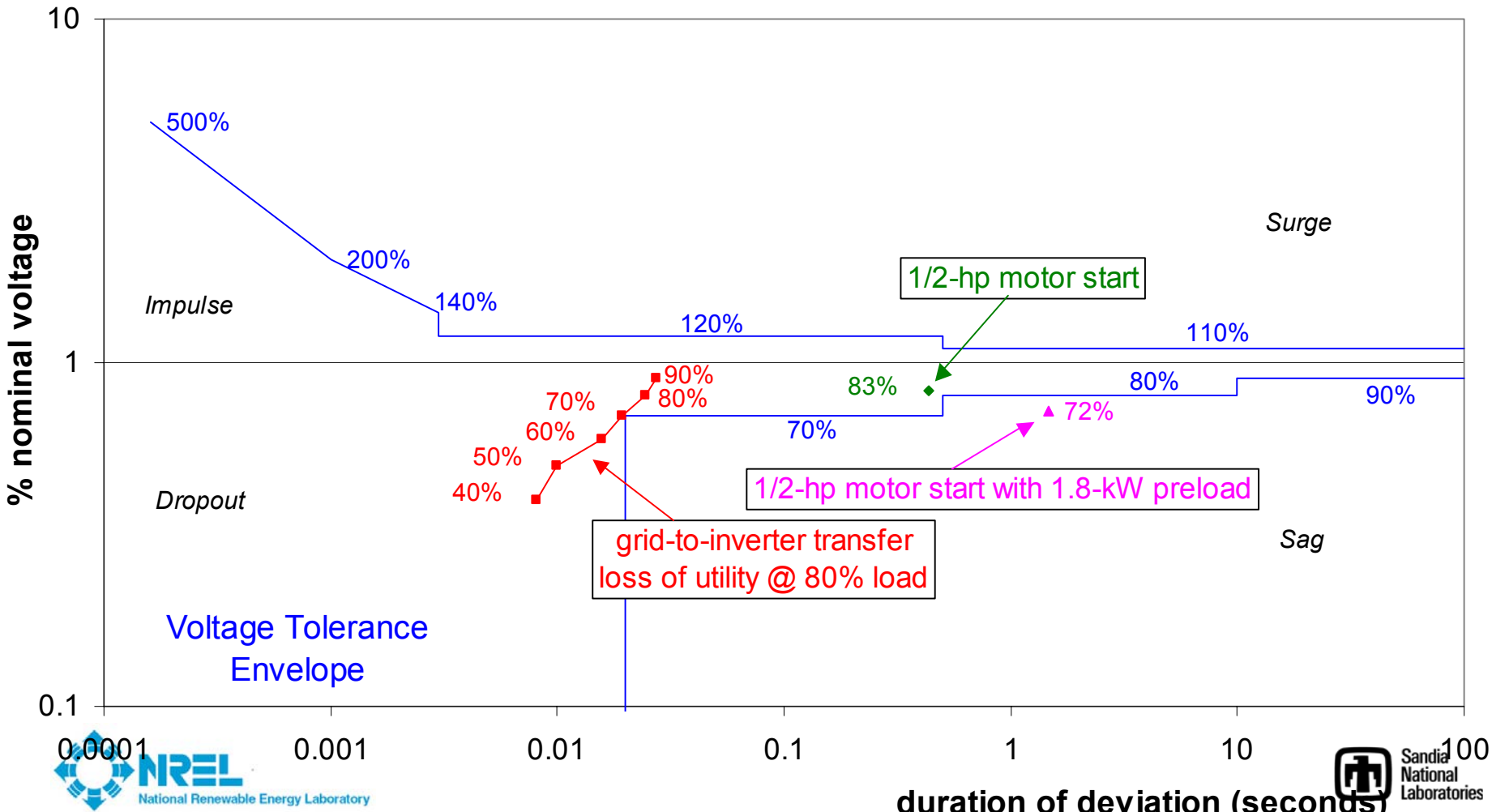
A Real-Life Example of Siting Considerations

Power Quality

- Voltage sags and surges – usually characteristic to a specific site
  - "Utility events" (lightning, switching, faults, motor starts, etc.)
  - Transfer to DG only operation
- Wave shape distortion – can be characteristic to a site or introduced by DG
  - Latter uncommon because of ease in meeting IEEE 519

Voltage Sags and Surges

CBEMA/ITIC curve sets a target for business equipment



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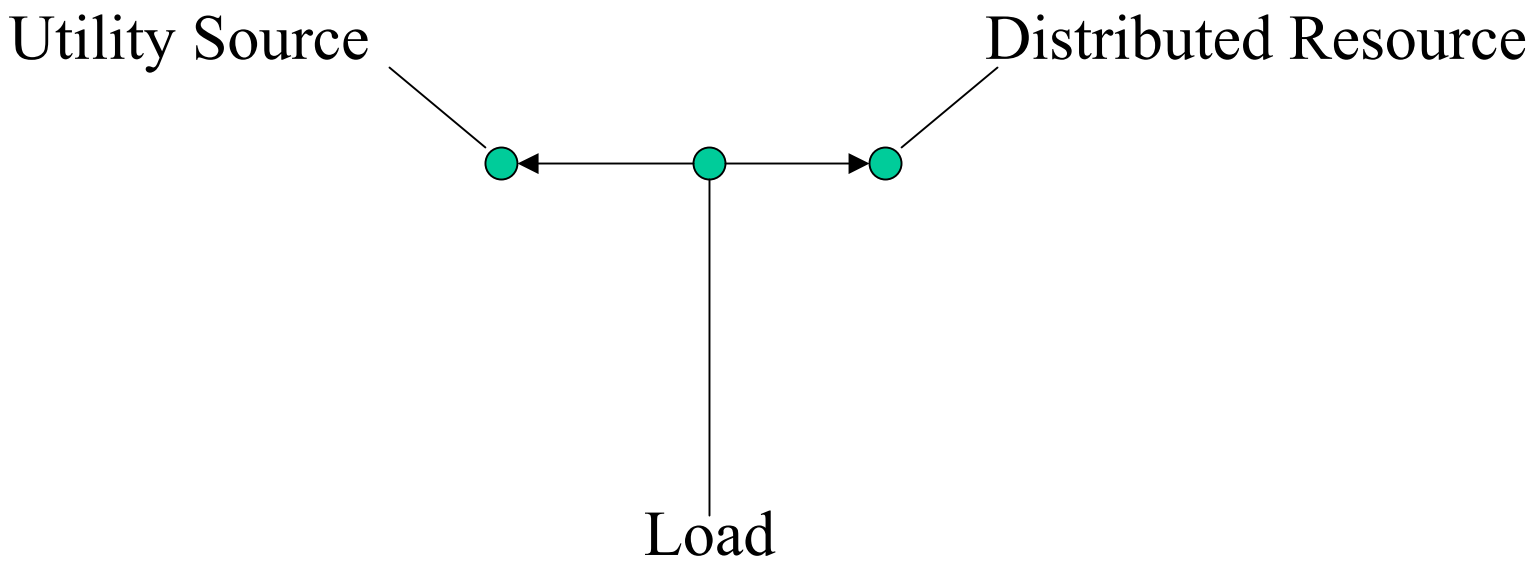
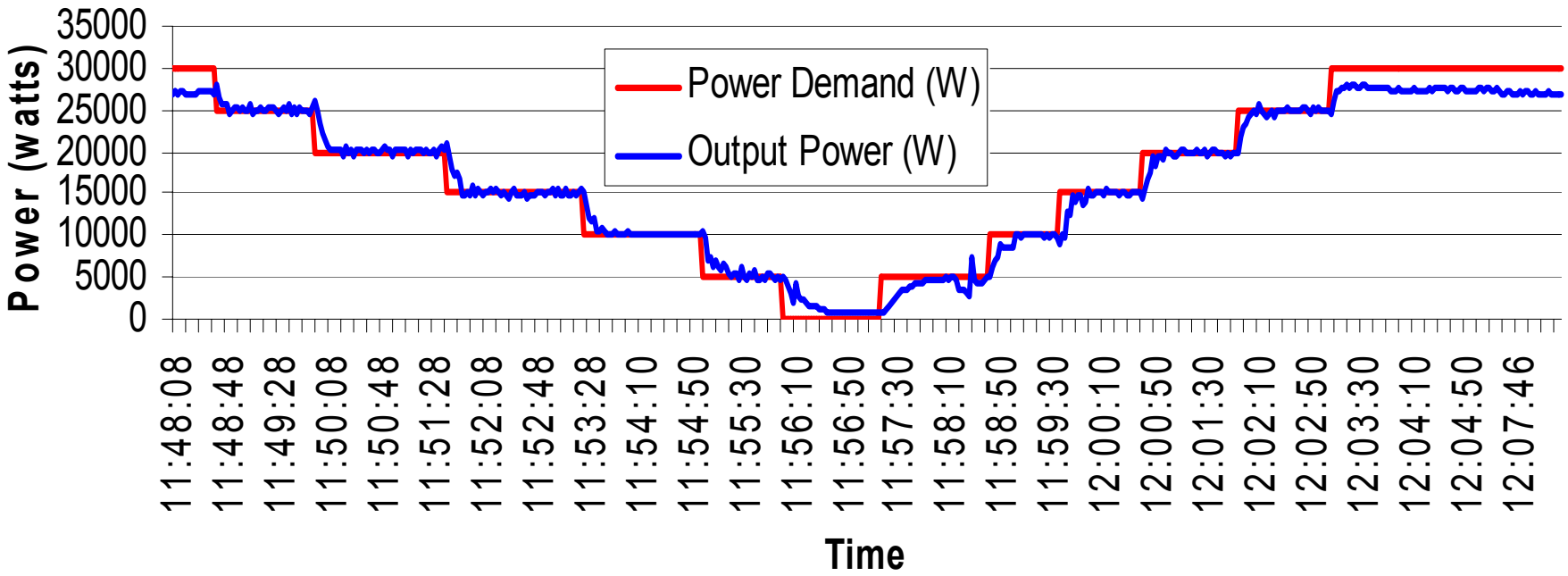
Normal Grid-Tied Operation

"Conventional"

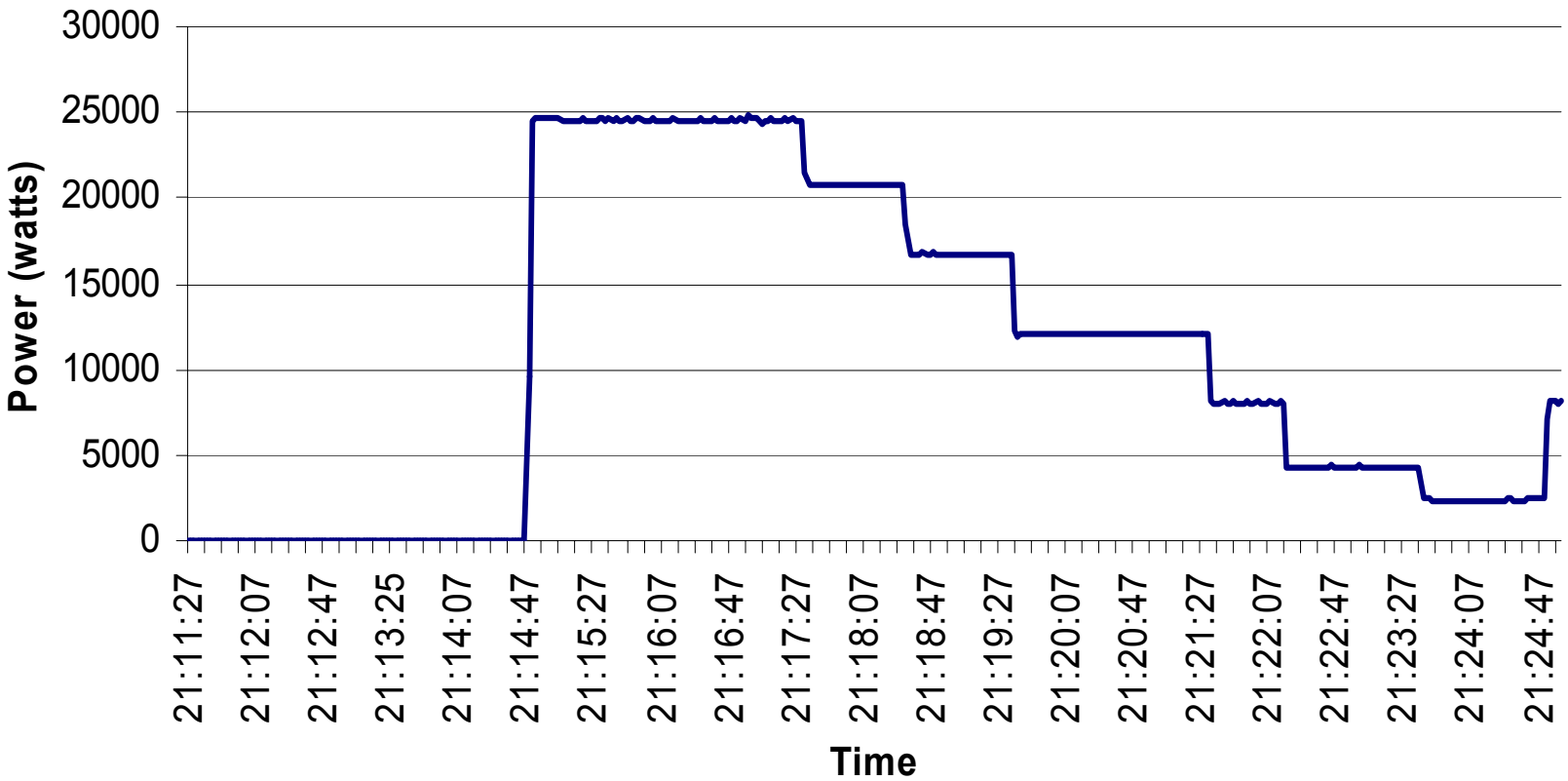


Capstone Load Following Capability (Grid-Tied)

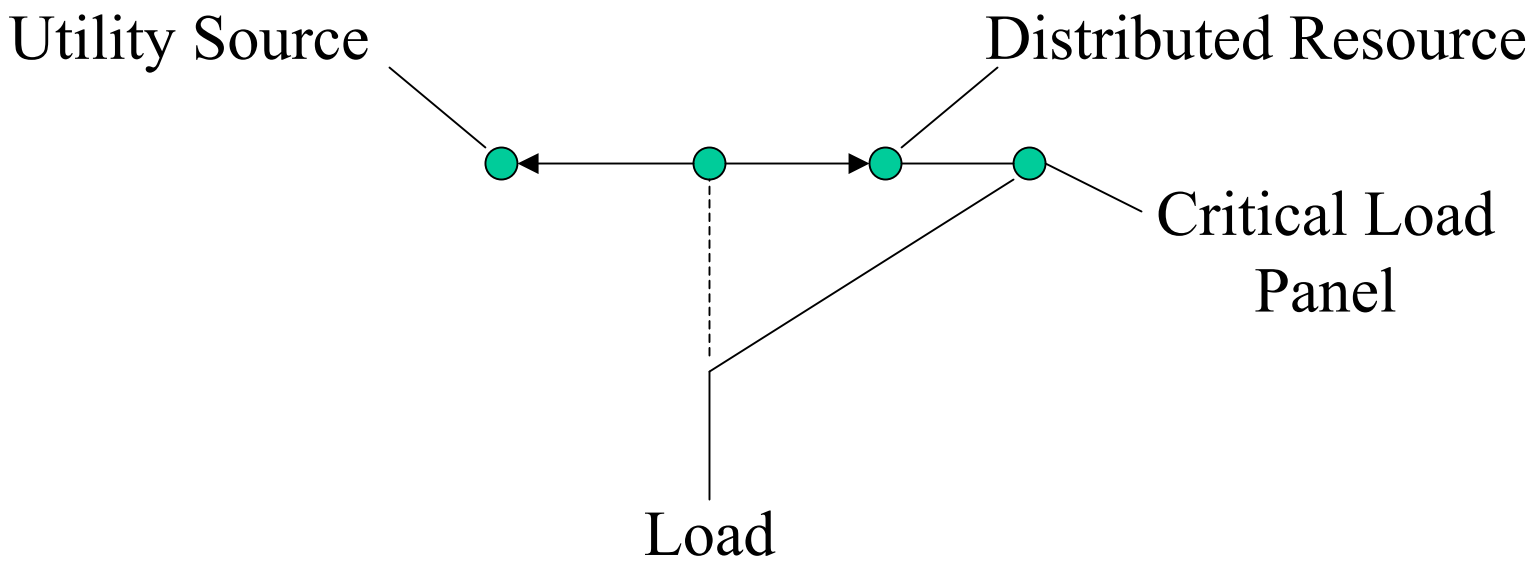
Note – No Sag Immunity



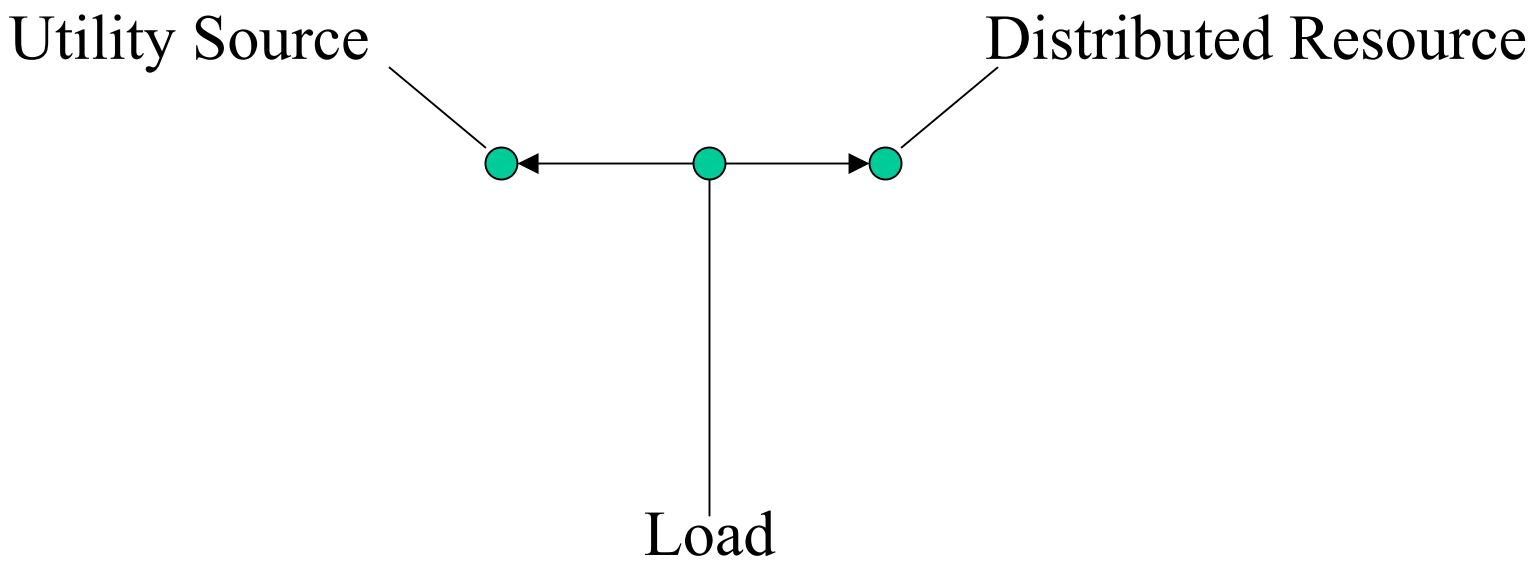
Capstone Load Following Capability (Stand-Alone)



If You Want Sag/Transition Immunity

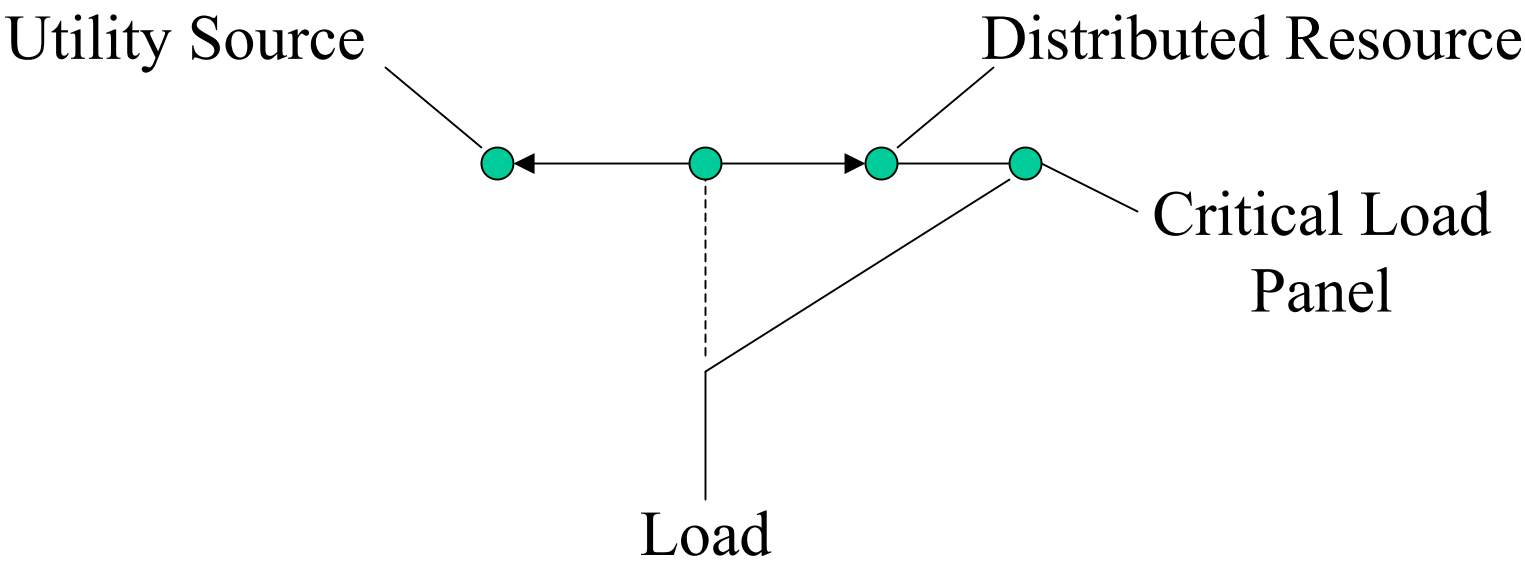


Connection is Key to Response During Transition From Grid-Tied to Stand-Alone



Load will see an outage

Connection is Key to Response During Transition From Grid-Tied to Stand-Alone



Load will <u>not</u> see an outage

Will DG Support Voltage During Sag or Transfer?

It depends!

If sag immunity is an important part of why you want distributed generation, then be certain the DG you buy has the capability to supply that immunity

Power Quality - Distortion

- Utility-interconnected installations are governed by IEEE standard 519
- Most manufacturers meet 519
- Stand-alone installations are heavily influenced by the load

Capstone

Capstone MicroTurbine™

CAPSTONE C30 High Pressure Gaseous Fuels

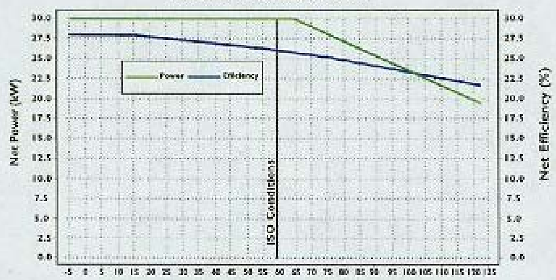
FEMP

The Product

Features
- Load-following 0-30 kW
- 360-528 VAC, 50/60 Hz
  (Stand-alone 360-480 VAC, 10-60 Hz)
  3-phase, 3- or 4-wire wye (4-wire for stand-alone)
  46ARMS/phase max continuous
- Grid-connect and/or stand-alone
- Maintenance-free air bearings
- No liquid lubricants
- No liquid coolants
- Sour gas tolerant (up to 70,000 ppm)
- Digital power controller
- Built-in display and user interface
- Built-in protective relays
- Built-in MultiPacking of 2-20 units
  (unlimited via grid connect)

Benefits
- Ultra-low emissions
- Minimal maintenance
- Direct2Grid™ interconnection
- No fluid storage, changes, disposal
- Uncontaminated exhaust heat for CHP
- Phase-to-phase balance (0-100%) on stand-alone units
- Small footprint
- Vibration-free, quiet operation
- Easy indoor/outdoor/rooftop siting
- Zero hardware arraying (up to 600 kW)
- Optional remote monitoring

C30 HP Net Power and Efficiency at Ambient Temperature, Sea Level



Compliances
UL 1741
UL 2200
IEEE 519
CEC Rule 21
NYPSC DG
EPA Exempt
CA AQMD Exempt
WY DEQ Exempt
NEMA 3R / IP 14
Others*

UL LISTED

CE

Other packaging options also available.

Full Load Specifications @ ISO Conditions (15°C / 59°F @ sea level)

Performance	Power	Efficiency (LHV)	Heat Rate (LHV)
Natural gas/gaseous propane (52-55 psig)	30 kW net (+0/-1) 30.2 kVA max @ 480 VAC	26% (± 2)	13,800 kJ (13,100 Btu) / kWh

Emissions:

NO_x	<9 ppmV @ 15% O_2 (<0.49 lb/MWh)

Intake/Exhaust

Fuel flow (natural gas/gaseous propane-HHV)	457,000 kJ/hr (433,000 Btu/hr)
Exhaust gas temperature	275°C (530°F)
Mass flow	0.31 kg/s (0.68 lb/s)
Total exhaust energy	327,000 kJ/hr (310,000 Btu/hr)

Dimensions
H: 1900mm (74.8")
W: 714mm (28.1")
D: 1344mm (52.9")

Weight
478 kg (1052 lb)

Sound
65dBA @ 10 m (33 ft)
CE Lwa 98 compliant

* See www.microturbine.com/compliance for detail
Fuel heat content: 27.8 to 93.8 MJ/m³ (760 to 2616 Btu/scf) HHV; natural gas, propane, methane, ethane.
The manufacturer reserves the right to change or modify, without notice, the design or equipment specifications without incurring any obligation either with respect to equipment previously sold or in the process of construction. The manufacturer does not warrant the data on this document. Warranted specifications are documented separately.

CAPSTONE TURBINE CORPORATION
www.microturbine.com

NREL National Renewable Energy Lab

Sandia National Laboratories